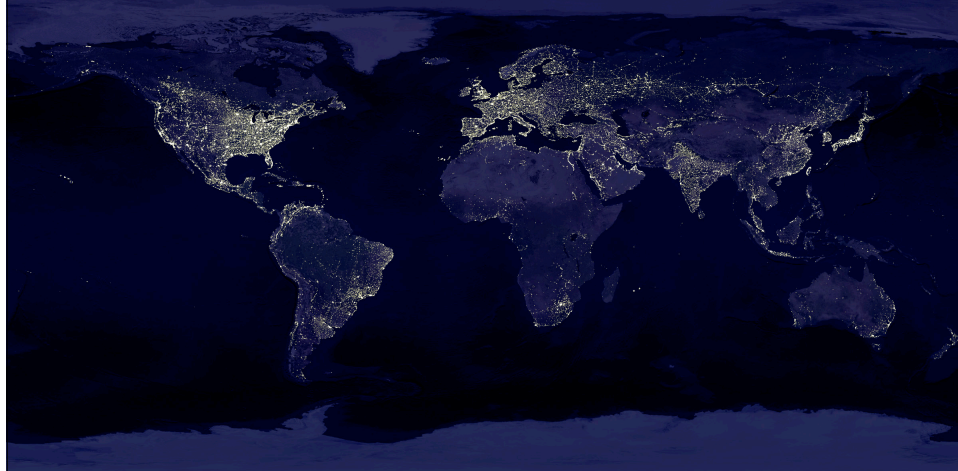


# The Specter of Fuel-Based Lighting...

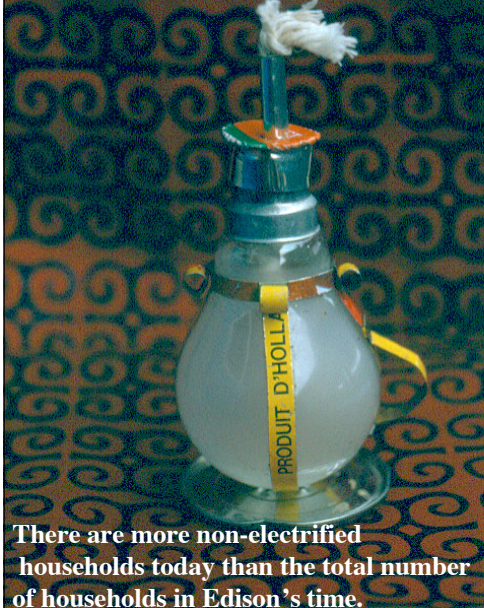


... A Dramatic Opportunity for Technology  
Leapfrogging in the Developing World

Evan Mills, Ph.D.

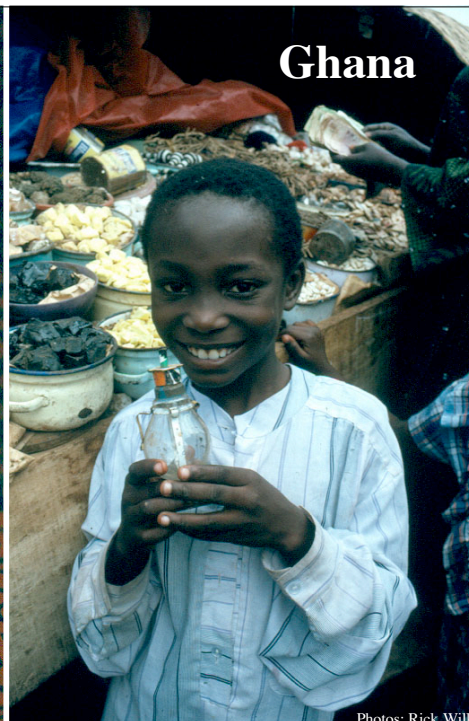
Lawrence Berkeley National Laboratory • <http://eetd.lbl.gov/emills>

**"We will make electricity so cheap  
that only the rich will burn candles"**  
- Thomas Edison



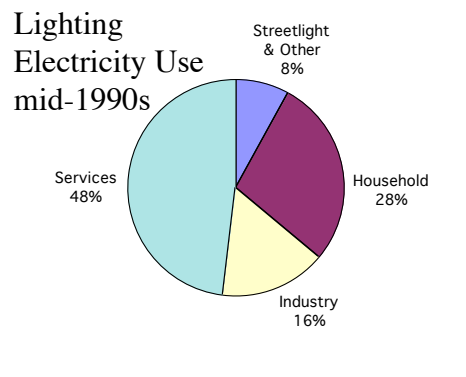
**There are more non-electrified  
households today than the total number  
of households in Edison's time.**

**Ghana**



Photos: Rick Wilk

# Global Lighting Energy: 178 Countries (Mills, 2002)

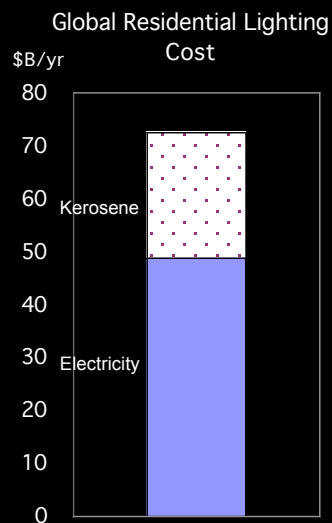


- Cost: \$185 Billion/year  
electricity \$25 billion fuel
- Power Plants: ~1000  
(400MW each)
- CO<sub>2</sub> Emissions: ~2Bt/year
- Direct Fuel: 1.4 Mboe/day  
(Brazil, Algeria, Libya, or Indonesia)
- Savings: \$75-\$115B/year  
(> Canada, France, or Germany TWh)

*Conservatisms: most estimates go back to mid-1990s; excludes HVAC-interactions; T&D losses at 10%; electricity price \$0.1/kWh; savings potential excludes daylighting*

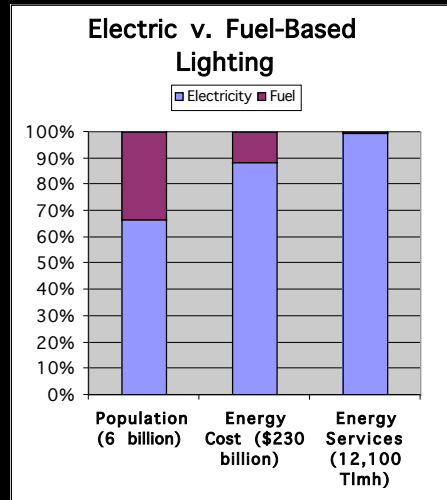
**An un-electrified household consumes as many lumens over an entire year as a single 100W incandescent bulb produces in 10 hours**

- Kerosene light costs 150-x more per unit of energy services
- Kerosene: 1.4 Mboe/day  
(~Brazil, Algeria, Libya, or Indonesia, or 50% of Iraq's oil production)

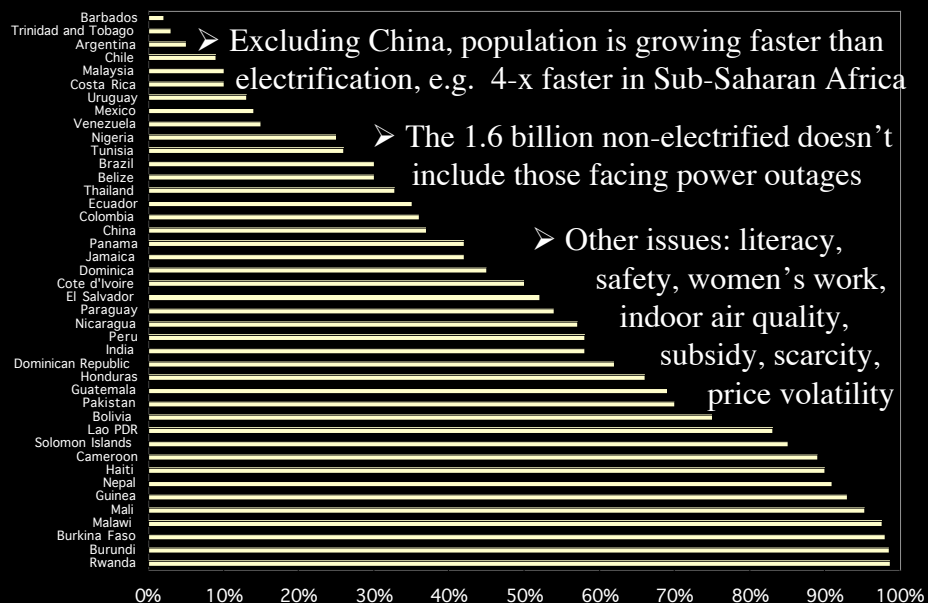


# Lighting Equity

Although one in three people obtain light with kerosene and other fuels, representing about 15% of global lighting costs, they receive only 0.2% of the resulting lighting energy services.

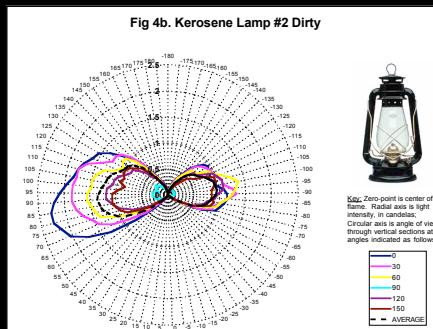
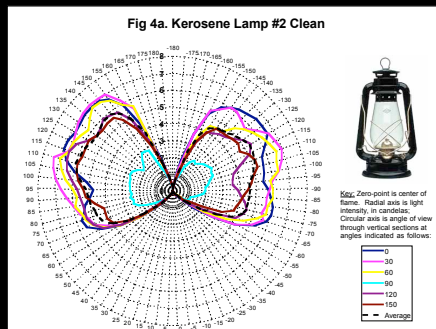
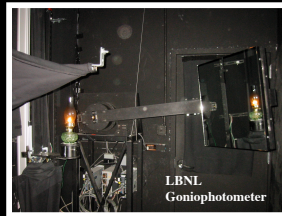


## Non-Electrified Population: mid-1990s



# Lighting Output and Performance of Fuel Lanterns is Poor

Laboratory tests show cross-sectional views of lighting intensity and distribution



## Tailor Alternative Designs for Intended Use



Photos: Evan Mills ©



## Think About Non-Household Uses

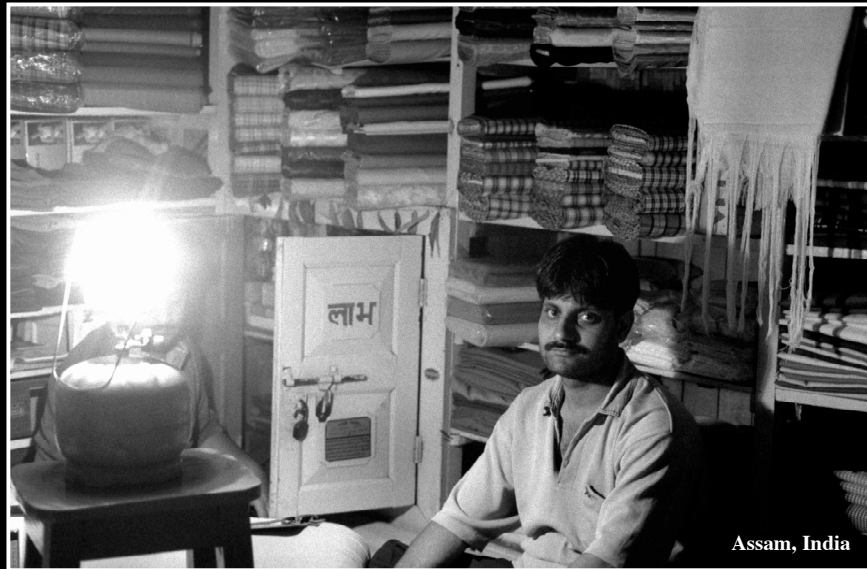


Photo: Evan Mills ©

## Non-Household Uses



Photos: Evan Mills ©

# Kerosene Kommerce

(Can existing sales channels be re-purposed?)



Northeast Viet Nam

Photos: Evan Mills ©

## Existing Sales Channels



Bhutan

Photo: Evan Mills ©

# Non-Energy Drivers (e.g. fire safety in temples)

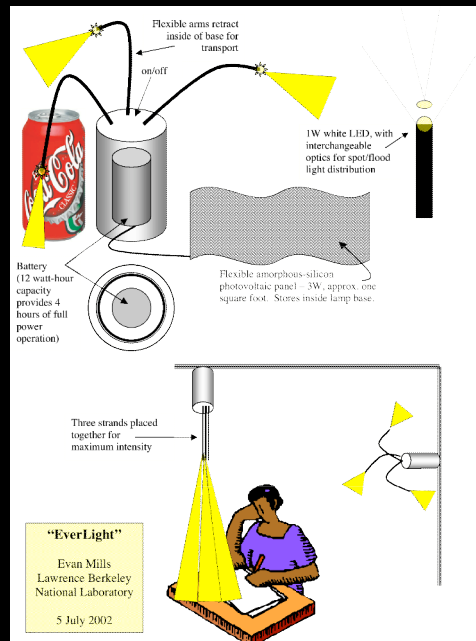


Bhutan

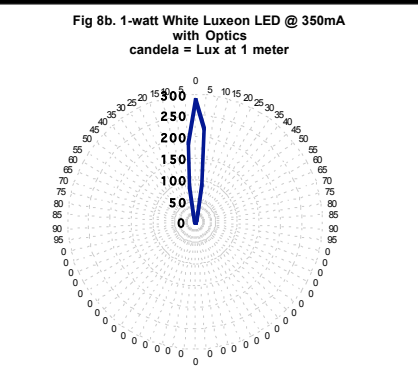
Photos: Evan Mills ©

## An Alternative: Light-Emitting Diodes (LEDs)

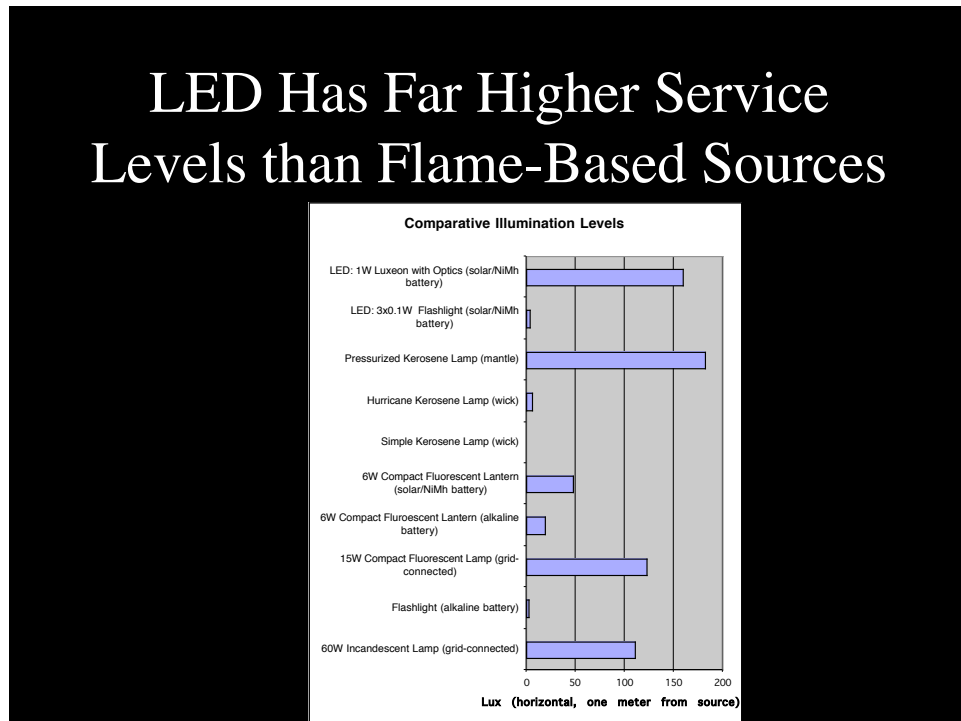
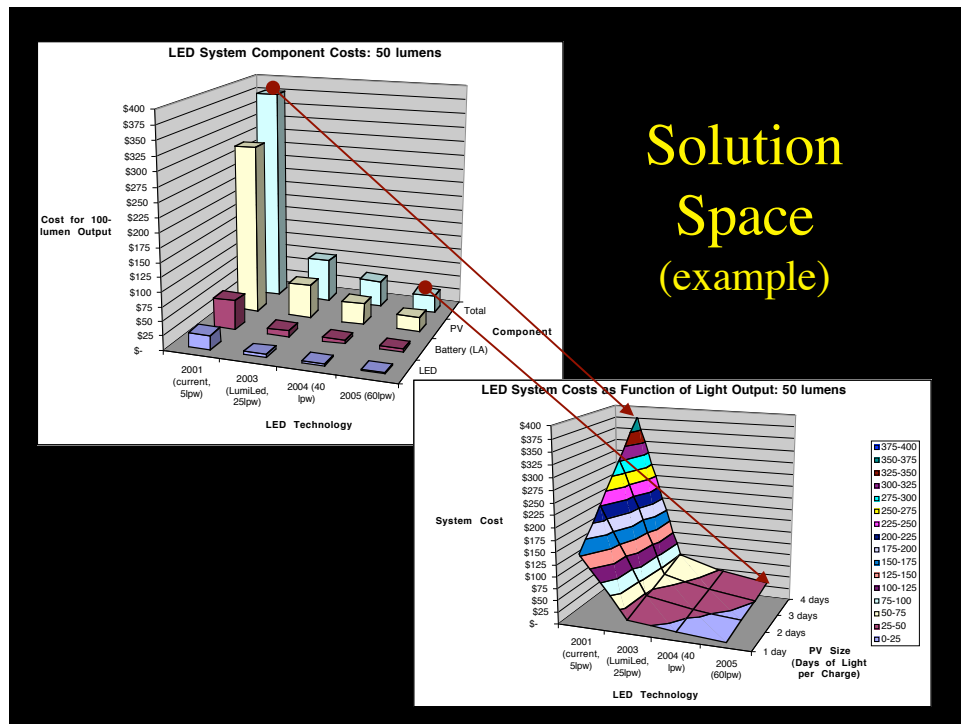
- Efficiency
- Versatility
- Portability
- Flexibility
- Ruggedness



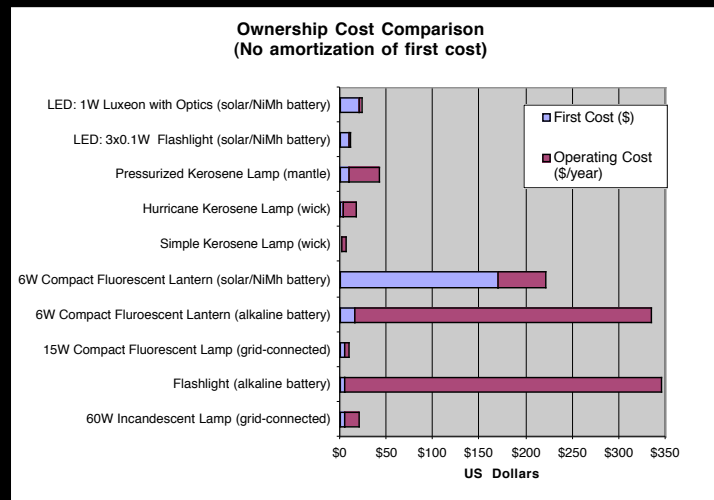
\* LED = Light-Emitting Diode





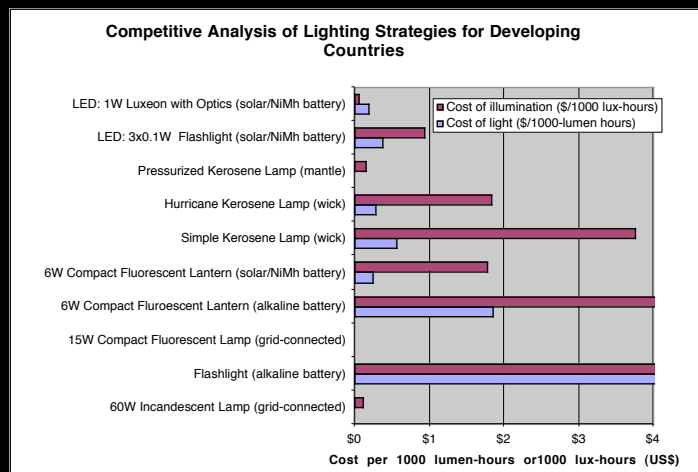


## Among Off-Grid Solutions, LED Approach Has Lowest Operating Cost



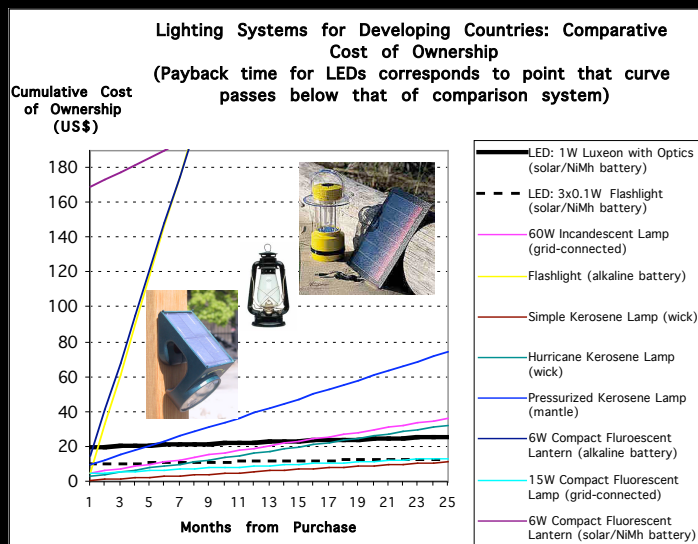
LBNL Analysis

## Among Off-Grid Solutions, LED Has Lowest Cost of Energy Services



LBNL Analysis

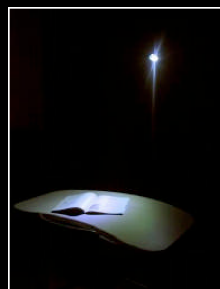
# LED Payback Time: 0.5-2 Years



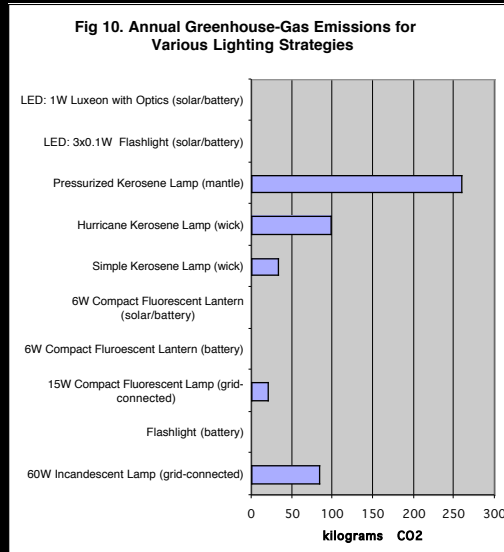
LBNL Analysis

## Stanford-LBNL Prototype

- Est. manufactured cost (before markups) ~\$10 [ses.stanford.edu]
- Annual Operating cost (replacement batteries) \$3 (\$15 for kerosene)



# Dramatic GHG Reductions



## Cost per Unit of Energy Services (\$/Lux-hour)

- Flashlights cost 1000x more than incandescent lighting from the grid (even at 20c/kWh)
- Non-pressurized kerosene lanterns cost 15-30x more
- Non-solar fluorescent lantern (4D disposable batteries) costs 120x more
- Traditional solar CFL lantern costs 10x more
- LED-PV System costs 60% LESS.
- LED-PV System provides 25x more useful light than a "bright" hurricane lantern and 150x more than a simple wick lamp.
- Each LED-PV System saves about 100 kg of Carbon Dioxide each year (compared to kerosene hurricane lantern) and 84 kg compared to grid-connected incandescent



## Next Steps

- **Better define markets\_ (res'l, non-res'l)**
- **Better define lighting needs/uses**
- **Develop and field test prototypes**
- **Explore alternatives to batteries**
- **Market/distribution challenge is greater than engineering challenge**

## More Information

[http://eetd.lbl.gov/emills/PUBS/Fuel\\_Based\\_Lighting.html](http://eetd.lbl.gov/emills/PUBS/Fuel_Based_Lighting.html)